The Effect of Diffusion Weighting on Activation - Induced ΔR2* / ΔR2 Ratio

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Introduction:

Diffusion weighting (DW) has been shown to reduce BOLD signal changes (1, 2). Explanations for this effect include: 1. Intravascular multi-directional flowing spins have a high apparent diffusion coefficient, and are therefore nulled with small DW. 2. Extravascular cerebral spinal fluid, (CSF), which surrounds larger pial veins and therefore contributes to BOLD contrast, also has a high diffusion coefficient, and therefore nulled with a small DW. With a change in susceptibility, the ΔR2*/ΔR2 ratio is dependent on the compartment size of the susceptibility perturber. Large ratios correspond to large compartments.

Our hypothesis is that if explanation 1 is the primary reason for BOLD signal attenuation, then the ratio should increase with DW, since the contribution of intravascular signal, having small compartment susceptibility perturbers (red blood cells), is reduced. If explanation 2 is the primary reason, then the ratio should decrease with DW since CSF signal experiences susceptibility gradients from large compartments only.

To test this hypothesis, synchronous gradient-echo and spin-echo echo-planar imaging SGS-EPI (3) was used to simultaneously collect gradient-echo (GE) and spin-echo (SE) time series pairs. DW was added in alternating time series. Comparisons of ΔR2* / ΔR2 with and without DW were made on a voxel - wise basis in regions that showed significant activation for both SE and GE acquisitions.

Methods:

SGS-EPI was performed using a local three axis gradient coil at 3T (Bruker). GE TE = 41 ms, and SE TE = 115 ms. TR = 1 sec. Matrix size = 32 x 32 (voxel volume = 7.5 x 7.5 x 10 mm^3). The shorter EPI readout allowed time for bipolar gradients (25 ms, 1.6 G/cm, b = 22.2 s^2/mm) prior to the GE readout. Two subjects were imaged. Two axial planes were obtained: one containing visual cortex and one of motor cortex. Subjects viewed a red 8 Hz flashing LED display (GRASS™ goggles), and performed bilateral finger tapping when the visual stimulus was on. Each time series was 80 sec. in duration. Stimulus timing was 20 sec. off, 20 sec. on, and 40 sec. off. The time between successive series was at least 2 minutes. Twenty time series were collected and spatially registered. In alternate time series, DW was applied, with all else being kept constant. Correlation analysis was performed to determine regions of motor and visual activation.

Results:

Figure 1 shows ΔR2* and ΔR2 changes, averaged from an ROI in the motor cortex of one subject, with and without DW. Attenuation of both ΔR2* and ΔR2 with DW during activation is apparent. The post-activation undershoot does not appear attenuated by DW.

Figure 2 is a voxel-wise comparison of ΔR2* / ΔR2 ratios. Most voxels show a small increase in ΔR2*/ΔR2 with DW, suggesting that the predominant effect of diffusion weighting is attenuation of intravascular signal and not attenuation of extravascular CSF. Voxels deviating from this trend may be those which contain vessels that also have CSF in extravascular space.

Table 1 is a summary of the average ΔR2*, ΔR2, and ΔR2* / ΔR2 ratio across all subjects and activated voxels.

Conclusions:

We demonstrate that not only does diffusion weighting reduce activation - induced ΔR2* and ΔR2 values, it also increases the ΔR2*/ΔR2 ratio in most voxels. This finding suggests that intravascular signal, consisting of small compartments (red blood cells), and having a ΔR2*/ΔR2 = 1.5 (4), contributes significantly to the measured ΔR2*/ΔR2 ratios. If intravascular signal can be completely removed, vessel radius may be more accurately inferred from these ratio measurements.

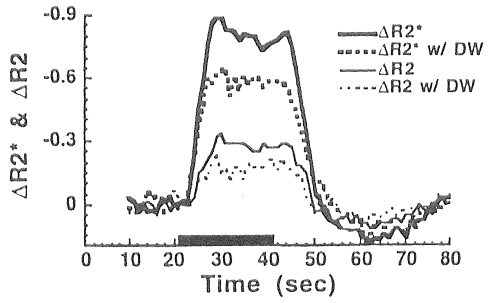

Figure 1: Activation - induced ΔR2* and ΔR2 changes with and without diffusion weighting (DW), measured from an ROI of common SE and GE activation.

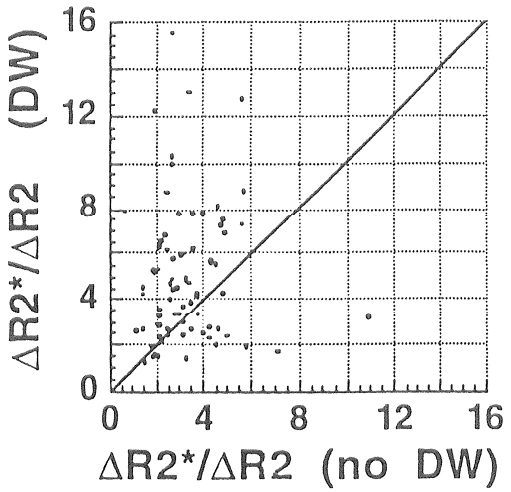

Figure 2: Scatter plot comparison of individual voxel ΔR2* /ΔR2 with and without diffusion weighting (DW).

	no DW	DW
ΔR2* / ΔR2	3.07 ± 0.07	4.12 ± 0.21
ΔR2*	- 0.67 ± 0.6	-0.52 ± 0.03
ΔR2	-0.22 ± 0.02	-0.14 ± 0.01

Table 1: Summary of measured relaxation rates and ratios with and without diffusion weighting (DW).

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